

Incremental and radical eco-innovations: routes for discovery and development

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Abstract

This paper presents the findings of an in-depth case study of a UK aerospace firm. Drawing on the Natural Resource Based View, we categorise the environmental capabilities of pollution prevention and product stewardship as incremental eco-innovations and clean technologies as radical eco-innovations. We select three new technology development projects as embedded units of analysis, each representing one of the NRBV's environmental capabilities. Using cross case comparisons, we identify barriers and enablers for incremental and radical eco-innovation development. We conclude that when the final product is complex, such as aerospace design, eco-innovations are developed in parallel with new product development teams co-developing knowledge using a process of embeddedness.

Keywords: eco-innovation, sustainable supply chain management, supplier involvement in new product development,

Introduction

Increasingly, organisations are moving beyond seeing sustainability as an exercise in compliance and cost reduction. Instead, they are realizing that competitive success depends upon the wellbeing of the environment and society (Bhupendra and Sangle, 2015; Luzzini et al. 2015; Wang et al. 2015). By viewing sustainability as creating 'shared value' organisations can view investment in the community as an investment in future markets (Porter and Kramer, 2011). The Natural Resource Based View (NRBV) argues firms can harness the natural environment to achieve a competitive advantage by developing three environmental capabilities; pollution prevention, product stewardship and clean technologies (Hart, 1995; 1997; Hart and Dowell, 2011).

Pollution prevention provides low cost competitive advantage by incrementally improving the production process through a focus on waste prevention. Product stewardship involves external stakeholders in lifecycle analysis activities, redesigning products for enhanced environmental performance. Using a strategy of competitive pre-emption firms secure exclusive access to rare resources, or establish an industry standard that is difficult for competitors to copy (Hart, 1995). Clean technologies are radical in nature and have the potential to disrupt entire industries (del Rio Gonzales,

2005). Examples of clean technologies include Toyota's hydrogen fuel cell used in electric cars or Tesla's Powerwall, a battery that gathers charge from solar panels to power homes at night. Organizations ambitious enough to pursue clean technologies achieve first mover advantages and quickly secure a future position in newly created markets (Hart and Dowell, 2011).

The underpinning requirement for the creation of environmental capabilities is innovation (Hart, 1997). If new technologies provide customer and business value but significantly decrease environmental impacts they can be defined as 'eco-innovations' (James, 1997). We categorize pollution prevention as an incremental eco-innovation because it makes small but continuous improvements to the production process to enhance environmental performance. Product stewardship is also classed as an incremental eco-innovation because it redesigns products for the environment but does not fundamentally alter market infrastructures. Clean technologies, which disrupt and fundamentally change the course of entire industries, are classified as radical eco-innovations.

The development of eco-innovations requires a shift in focus from local supply chain optimisation to the entire supply network (Carillo-Hermosilla *et al.*, 2010). Recent research (Mylan *et al.*, 2015) emphasises this point by finding that eco-innovations are more likely to result from collaborative relationships between the focal firm and its suppliers. Moreover, supplier involvement in clean technology development has been found to become increasingly important the more radical the technology becomes (del Rio Gonzalez, 2005). Supply chain scholars have recently called for urgent investigation into how firms can work closely with their supply network to co-develop radical eco-innovations (Pagell and Shevchenko, 2014). We respond to this call by posing the question: "*What are the enablers and barriers for successful eco-innovation development?*"

To answer this question, we apply and test a conceptual three-stage typology for developing eco-innovations (Roscoe *et al.*, 2016) to a case study of a high technology aerospace firm. Within the context of a single case we isolate three new technology development projects as the embedded units of analysis, each representing one of the NRBV's environmental capabilities. Using within case and cross case comparisons we identify key enablers and barriers to eco-innovation development.

Literature Review

Eco-innovations focus on the development of sustainable products and processes for increased competitive advantage (James, 1997; Carrillo-Hermosilla *et al.* 2010). They can be classed as either incremental or radical, with incremental eco-innovations referring to gradual and continuous competence-enhancing modifications that preserve existing production systems and sustain existing networks. Radical eco-innovations are competence-destroying, discontinuous changes that seek the replacement of existing components or entire systems and the creation of new networks (*ibid*). Eco-innovation development has been advanced by some scholars as a way to achieve competitive advantage. For example, Pujari (2006) found eco-innovation development enhanced market performance. Klewitz *et al.* (2012) found improvements in competitiveness and reductions in environmental impact to be achieved by implementing eco-innovations. Moreover, Mylan *et al.* (2015) found the development of eco-innovations enhanced the environmental and supply chain performance of three leading UK supermarkets.

The NRBV asserts a firm's competitiveness is constrained by and dependent upon the natural environment (Hart, 1995). Sustained competitive advantage is achieved through the interconnected development of pollution prevention, product stewardship

and clean technology capabilities (Hart and Dowell, 2011). The NRBV presents two, somewhat contradictory, routes for the development of environmental capabilities: embeddedness (Dierickx and Cool, 1989) and path dependence (Barney, 1991). Path dependence suggests a particular sequence of resource accumulation, where a firm must first invest in resources at the pollution prevention stage before advancing to product stewardship and clean technology initiatives. Embeddedness suggests resources are accumulated in parallel. By investing in resources such as green manufacturing technologies the firm eliminates waste in the production process (pollution prevention) enabling a faster response in the marketplace which, in turn, facilitates a strategy of competitive pre-emption (product stewardship) and future strategic positioning (clean technologies) (Hart, 1995). Despite proposing these two different paths of development, the NRBV provides limited empirical evidence on which route firms adopt in practice.

Roscoe et al. (2016) draw on the NRBV and social network theory to suggest three routes for eco-innovation development. They argue that incremental eco-innovations are developed by building strong ties to strategic suppliers. The creation of strong ties leads to knowledge and technology spilling-over from the supplier to the firm during the NPD process (Mayer, 2006; Perols et al. 2013). Yet, because the buyer and supplier exist within the same strong tie cluster they tend to share homogeneous ideas (Granovetter, 1973) resulting in only incremental improvements on existing technologies (Roscoe et al. 2016). To find radically different ideas the buying firm needs to build weak ties to suppliers outside of its strong tie cluster. If the supplier acts as a bridge between industries, the buying firm can access the knowledge and information of an entirely different network via a single contact (Burt, 2004, Rapoport and Horvath, 1961; Autry and Griffis, 2008).

Research Method

We apply the Roscoe et al. (2016) typology to a single case study of a UK aerospace firm to determine the barriers and motivators for eco-innovation development. The case study format offers in-depth data gathering and analysis opportunities (Dyer and Wilkins, 1991; Voss et al, 2002). A single case design allows an even deeper level of investigation into a given phenomenon versus multiple cases (Sigglekow, 2007). Moreover, a single case allows the researcher to control for externalities that may play an unobserved role when comparing across companies or industries (Yin, 2009). Within the single case context, three eco-innovation development projects are selected and studied in detail; they are used as the unit of analysis each representing an incremental (pollution prevention/product stewardship) or radical (clean technology) eco-innovation.

Titanium Aluminide (TA) is selected as the pollution prevention eco-innovation because it replaces a nickel super-alloy which contains rare earth elements and carcinogens. TA does not use rare earths and is easier to form during manufacture, consuming less energy and generating less waste. The product stewardship eco-innovation, carbon composites, is a light weight alternative to titanium that removes significant weight thereby decreasing fuel burn and lowering emissions. We studied the triad formed between the case company, a strategic supplier, and the joint venture company responsible for developing the technology. This triadic configuration is termed a 'balanced state' where the buyer has a cooperative relationship with each supplier and the suppliers have a cooperative relationship with each other (Choi and Wu, 2009). Studying this triadic configuration allows us to isolate the barriers and enablers of building strong ties with suppliers during incremental eco-innovation development.

Additive Layer Manufacturing (ALM), or 3D printing, represents the radical, clean technology, eco-innovation. ALM is seen as a disruptive technology that could

transform the industry; it uses high quality metal powders to produce near net shape components, removing up to 85% of waste from the production process. We studied the triad formed between the case company and two unconnected suppliers. This is termed a 'structural hole' triadic configuration where the buyer sits on top of the structural hole between two suppliers and has a cooperative relationship with both suppliers (Choi and Wu, 2009). Studying this triadic configuration allowed us to isolate the barriers and enablers of building weak ties to suppliers during radical eco-innovation development. Moreover, it allowed us to investigate how building weak ties to suppliers that bridge structural holes between industries helps or hinders radical eco-innovation development.

To improve reliability we used a triangulated data collection method (Yin, 2009) including forty-six semi-structured interviews, eight focus groups and validated through objective and secondary data sources. A snowball sampling technique was used to select each interviewee (Taylor and Bogdan, 1998). Data collection stopped when a point of theoretical saturation was reached, or when additional data did not provide new information or understanding (Eisenhardt, 1989). NVIVO 10 software was used to code the interview transcripts, focus group notes and company documentation. Using hierarchical coding, groups of similar codes were clustered together to produce more general higher order codes, or themes, which give a rich story about the case (King, 2004, Eisenhardt and Graebner, 2008).

Findings

Following analysis of the data two overarching themes emerged, we label these: Enablers and Barriers, because they appear to be either enhancing or restricting the firm's ability to develop eco-innovations. We first address the enablers and barriers of developing incremental (pollution prevention & product stewardship) eco-innovations and then turn our attention to radical (clean technology) eco-innovations.

Enabler 1: Creating shared value

The findings suggest the case company is dedicated to pursuing a shared value strategy by incorporating social and environmental considerations into the culture and strategic focus of the organization. This strategy builds upon and leverages the unique resources and expertise of the organisation. As part of this strategic approach the case company established an organisational lead through a VP for Sustainability. The VP argued there was no need for additional sustainability training because sustainability was deeply embedded in the corporate strategy (see table 1): *"No training courses. If we develop a strategy that's hardwired in to the business, when you raise a purchase order, when you make a decision, you don't need to see sustainability as added on. It has to be central to all you're doing."* Pagell and Wu (2009) call this 'integration' arguing that managers need to integrate sustainability goals, practices and cognitions into day-to-day operational activities.

Once the strategies were aligned, the global sustainability team convinced members of the Board to act as sustainability champions giving them responsibility for disseminating the new strategy across the organization (see table 1). One manager in the team explains: *"you need to go straight to the leaders first and try and get them to understand the value of it or the importance and what needs to be done, and get a few of them to almost be your champions or your inside men...so they're already advocates so they would have already joined those dots up."* Senior level sustainability champions helped facilitate the roll-out of the new strategy as employees could immediately see the strategic importance of sustainability and its relevance to their day-to-day role. Nine individuals from across the organization including forward sourcing, future programmes

and manufacturing technology commented how strategic alignment helped them understand and buy-in to the new sustainability initiative (see table 1).

At the same time, the senior management team focused the organization's attention on the development of its 'top 11' technologies including TA, carbon composites and ALM. The case company demonstrated a proactive corporate environmental stance (Bowen et al. 2001, Sharma and Vredenberg, 1998) by assigning integrated project teams and nominating a technology champion to drive each technology forward. Four interviewees commented on how technology development lead times dramatically improved once the teams were established (see table 1).

Table 1: Eco-innovation enabled by a 'shared value' approach

n=number of respondents	SRC n= 6	Fwd. Source n= 4	Fut. Prgrns. n=9	R&T n=3	Rotatives = 1	Man Tech n=6	GTSC n=1	Eng. & Trans n=2	S&T n=1	Turbines n=2	CCIPT =1	Global Sustainability n=4	Supplier 1 n=3	Supplier 2 n=3	Total n=46
Enabler 1: Creating Shared Value	1	2	4			2				1		4		3	17
Aligning sustainability and corporate strategy enabled senior management buy-in												4			4
Alignment to corporate strategy allows all individuals in organization to understand sustainability strategy		2	4			2						1			9
As sustainability and corporate strategy aligned do not need additional sustainability training												1			1
Senior Level Champions facilitated dissemination of sustainability strategy												3			3
Integrated Project Teams have improved technology development lead times	1					1				1				1	4
Technology champions have driven development forward														3	3

Enabler 2: Creating a sustainability value proposition

Interviewees indicated the majority of customers viewed cost and performance (fuel burn) as order winners. However, some interviewees suggested a handful of customers were beginning to compete on a sustainability platform. A Senior VP explained these forward thinking customers expect the case company to demonstrate the environmental and social performance of their internal operations and end-to-end supply chain “We’ve just been with one customer last week who are really making a very strong play on sustainability and will be requiring all their suppliers to be very clear about the sustainability of their products down to a very low level of detail, so that’s becoming all the more important. It will flow through to suppliers.” The case company is positioning itself to win these customer orders by developing a sustainability value proposition based on enhanced visibility of the environmental and social performance of the extended supply chain.

Enabler 3: Competitive Pre-Emption

Product stewardship provides a sustained competitive advantage through a strategy of competitive pre-emption (Hart, 1995). A company can pre-empt competitors by establishing a reputation as a “green” company; winning orders based on a customer’s perception of its environmental performance (Rusinko, 2007). Product stewardship can also help differentiate the firm’s products by establishing the firm as an early mover in green product domains (Menguc and Ozanne, 2006). Our findings suggest the case company is actively pursuing a strategy of competitive pre-emption in the development of carbon composites. Although the competition already uses carbon composites the

case company is pre-empting the future trajectory of the technology by enhancing the material's environmental performance. The case company has built strong ties with a strategic supplier to develop the technology, forming a joint venture and allocating skilled engineers to the new project structure.

Within the newly formed project structure, the buyer-supplier team employ Design for Environment (Fiksel, 1996) and Life Cycle Analysis techniques (Welford and Gouldson, 1993). The team focuses on reducing materials to create environmental benefits by reducing weight and using less raw composite material. They are also rethinking manufacturing techniques to improve environmental performance. Finally, the team is exploring how to reuse the composite material at the end of life. This poses a significant challenge as the composite fibres are difficult to split apart and re-process. The team is exploring putting chopped fibres through an industrial sized shredder with excess material reused in future product designs.

Enabler 4: Future Strategic Positioning

The key resource in clean technology development is innovation which drives disruptive change (Hart and Dowell, 2011). Competitive advantage lies in being the first to market with the innovation; securing a future position for the firm and blocking the competition from doing likewise. The ALM project highlights how the case company and its competitors are adopting two different strategies to secure a future strategic position in the manufacture of components. The competition is positioning itself using a strategy of acquisition. Conversely, the case company is positioning itself using a strategy of organic growth; casting a wider net and developing multiple applications simultaneously. The case company has created weak tie relationships with small additive machine suppliers situated outside of its existing strong tie cluster. These suppliers are locked into a path of development where the technology is customized to the case company's specific requirements. The use of proprietary manufacturing processes inhibits imitation and substitutability, leading to improved competitive positioning. The case company established further barriers to imitation by patenting specific parts of the manufacturing process, leading to a sustained competitive advantage for the firm.

Enabler 5: Using suppliers as bridge to new industry knowledge

The development of radical (clean technology) eco-innovations is also enabled by building weak ties to suppliers that bridge structural holes between industries. Companies that bridge structural holes occupy powerful brokerage positions as they arbitrate the information flows between densely knit clumps of strong ties (Kogut, 2000). The findings suggest the case company formed a weak tie relationship with a supplier because it could transfer its experience of ALM from the medical sector to aerospace. Since 1999, the supplier used plastic polymers to additive manufacture prosthetics for the medical industry. In 2006, the supplier began additive manufacturing using high quality metal powders including titanium based powders. Building weak ties with this supplier allowed the case company to access the knowledge and experience of the medical industry providing new ways of thinking and a head start in development.

Barriers to developing eco-innovations

Barrier 1: Pollution prevention initiatives implemented primarily in internal facilities

The findings suggest the case company implements most pollution prevention initiatives in internal facilities. This is an interesting finding because up to 80% of the value of the

final product is produced in the supply chain. A robust set of metrics is in place to measure the energy usage, CO2 emissions and waste from internal production facilities. However, strategic suppliers are only expected to comply to these metrics, with most indirect suppliers escaping measurement. Supply chain scholars argue that investment in environmental technologies cannot be made independently of other organizations but must include suppliers (Klassen and Vachon, 2003; Vachon and Klassen, 2007).

Three interviewees felt cost reduction, not environmental performance, was the primary driver in preventing pollution in the supply chain. Pagell and Shevchenko (2007) argue companies pursuing pollution prevention initiatives based solely on costs will hit a productivity frontier where no further gains can be achieved. Alternatively, seeing pollution prevention as an exercise in environmental performance enhancement provides longer term productivity benefits (Vachon and Klassen, 2007). The findings suggest that extending environmental metrics to direct and indirect suppliers and enforcing compliance could overcome the barrier of implementing pollution prevention strategies in the supply chain.

Barrier 2: End-of-life not a primary design consideration

Although design for environment and life cycle analysis techniques were applied in the carbon composite case, such practices were less apparent in the overall design process, in particular the reuse and disposal of products at the end-of-life. An interviewee working in the design department explains the issue: *“That does feel secondary, so when we’re designing we think pretty hard about how efficient something’s going to be and the environmental side of things. I’m not quite sure that we think fully about what we’re going to do with it at the end of the day.”* It appears the case company is taking the position that because the final product is sold on to a customer, its end-of-life becomes the responsibility of that customer. However, a robust life cycle analysis closes the loop of the supply chain ensuring end-of-life is captured during design (Guide et al., 2003).

Barrier 3: Novelty of radical eco-innovations leading to underdeveloped capabilities

The findings suggest that due to the novelty of radical eco-innovations both the buyer and supplier have underdeveloped NPD capabilities. Despite using plastic polymer powders for some time, additive manufacturing using high quality metals only become viable in 2006. Fourteen interviewees felt the existing pool of ALM suppliers had underdeveloped capabilities particularly when working with metal powders. Although many suppliers had developed prototypes for other industries, few have experience delivering to the stringent aerospace requirements. One interviewee explains: *“the supplier maturity overall is very very low. And the knowledge to understand how it applies to aerospace isn’t there....these suppliers have been born out of rapid prototyping making parts for all sorts of different industries....that aerospace rigour is very different.”* The situation is further complicated by a lack of machine capacity and raw material suppliers. The suppliers investigated for this paper only had six machines capable of using metal powders. To productionize ALM on a large scale, the case company will require over one hundred machines. Lack of capacity limits the technology to prototyping until investment is made in additional machines or demand is spread across a limited pool of capable suppliers.

Lawson et al. (2015) argue that suppliers often lack the technological capabilities needed to undertake collaborative new product development (NPD). We found that due to the novelty of radical eco-innovations both the buyer and supplier had underdeveloped NPD capabilities. As both parties had underdeveloped capabilities they

were forced to enter into an interdependent relationship, sharing and integrating knowledge in a mutually dependent manner. Knowledge was co-developed between the two parties as they gathered and debated new information throughout the NPD process. This finding suggests the development of radical eco-innovations requires sophisticated knowledge management capabilities where the buyer and supplier share knowledge within a symbiotic relationship.

Barrier 4: Appropriability regimes

Radical eco-innovation development was further inhibited by a reluctance to share intellectual property. The case company attempted to own all of the newly created intellectual property (foreground IP) during the NPD project. The objective was to maintain ‘executable choice’ where IP agreements did not tie the case company to any one supplier but provided the freedom to utilize IP as it sees fit. Twenty-two interviewees, including the supplier, stated this approach created tension in the buyer-supplier relationship as the supplier was not willing to part with IP it helped create (see table 2).

Table 2: Radical eco-innovation inhibited by intellectual property ownership

	SRC n= 6	Fwd. Source n= 4	Fut. Prgrms. n=9	R&T n=3	Rotatives n=1	Man Tech n=6	GTSC n=1	Eng. & Trans. n=2	S&T n=1	Turbines n=1	CC IPT n=1	Global Sustain. n=4	Supplier 1 n=3	Supplier 2 n=3	Total n=46
Barrier 4: Intellectual property ownership inhibiting radical eco-innovation development	1	3	4	1		5	1	2	1	1	2			1	22
Need clear IP ownership strategy early on in supplier relationship		1	1	1		5	1	1	1		1			1	13
Case company attempts to own all foreground IP in NPD projects with suppliers to maintain executable choice	1	1	2	1		1	1	1	1						9
IP ownership creates issues when working with suppliers to develop ALM		2	1	1		3	1	2	1	1				1	13
If collaborative relationship in place IP can be shared with suppliers							1	2	2		2			1	8

Strategic management scholars argue that intellectual property, patents and copyrights are often ineffective and can easily be circumvented by competitors (Teece, 1988; Hurmelinna-Laukkanen et al., 2008). Competitive advantage is more readily achieved by establishing appropriability regimes through the development of co-specialised assets (ibid). Instead of solely relying on intellectual property rights, the case company could combine its tacit knowledge of radical eco-innovation development with the supplier’s expertise in additive machining. Creating co-specialized asset combinations makes it difficult for competitors to appropriate innovation, generating a sustained competitive advantage for the firm (ibid).

Conclusion

This paper makes a theoretical contribution to the NRBV by providing empirical evidence that environmental capabilities are not necessarily developed in a path dependent manner, but instead through a process of embeddedness. Using three embedded cases as units of analysis, we found that when the final product is complex and highly safety critical, as in the case of an aerospace design, buyer and supplier teams will work in parallel to co-develop eco-innovations. Knowledge and competencies co-evolve between new product developments teams, with advances in

the environmental performance of one technology enabling advances in another. To ensure all eco-innovations function harmoniously in the final product, buyer-supplier teams must share and integrate knowledge within and across team boundaries.

Moreover, the paper provides empirical data to support the Roscoe et al (2016) three stage typology of eco-innovation development. The carbon composite case shows that building strong ties to strategic suppliers is more likely to result in the development of incremental eco-innovations. The ALM case highlights how building weak ties to suppliers is more likely to result in radical eco-innovation development. If the firm is able to build weak ties to suppliers that bridge structural holes between industries, it can benefit from new knowledge and radically different ways of thinking.

Practically, the paper presents to managers the key enablers and barriers of eco-innovation development. Enablers include adopting a shared value approach and creating a sustainability value proposition. Product stewardship eco-innovations are enabled through a strategy of competitive pre-emption where the firm becomes a market leader in both economic and environmental performance. The novelty of radical eco-innovation means both buyer and supplier have underdeveloped NPD capabilities requiring the co-development of knowledge within a mutually dependent relationship. Relationship barriers can be overcome by sharing intellectual property and erecting appropriability regimes which are difficult for competitors to copy.

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